(12) UK Patent Application (19) GB (11) 2 186 337 (13) A

(43) Application published 12 Aug 1987

(21) Application No 8702367

(22) Date of filing 3 Feb 1987

(30) Priority data

(31) 8602716 (32) 4 Feb 1986 (33) GB

(51) INT CL[4]
F16H 53/00

(52) Domestic classification (Edition I)
F2K 3A2A 3A2C3 3B2C 3B2D 3B3A 3B4B
F1B 2P2C 2P2D 2P2K2C B130 BC
U1S 1820 1990 F1B F2K

(56) Documents cited
None

(58) Field of search
F2K
F1B
Selected US specifications from IPC sub-classes F01L F02D F16H

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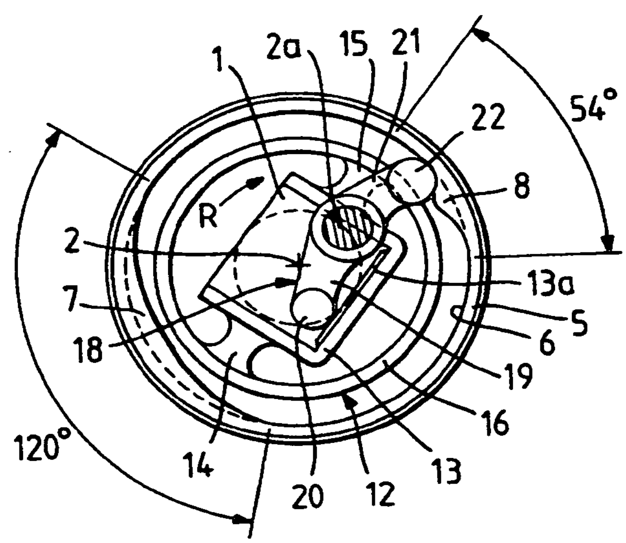
# (54) Cam arrangements

(57) A cam arrangement, which enables the profile of a valve event to be varied and high-lift, short-duration valve events to be achieved, employs an annular cam (5) concentric with an axis (2) of a camshaft (1). The cam (5) is angularly adjustable about the axis (2) to position different eccentric portions (7 and 8) of an internal cam profile (6). A box-section (13) of a slider (12) having an output ring (16) is reciprocably received on a square section portion of the camshaft and is displaceable by a lever (18) pivotally mounted on the camshaft (1) for rotation about a pivot axis (2a). Lever (18) has a follower (22) engaging the cam profile (6) and an actuator engaging abutment surface (13a) of the box-section (13). In another embodiment (Fig. 1) a high-lift short-duration cam portion (8) is formed by a rotatable lift cam carried by the annular cam (5) and rotatable synchronously with the camshaft.

Fig. 2.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1.

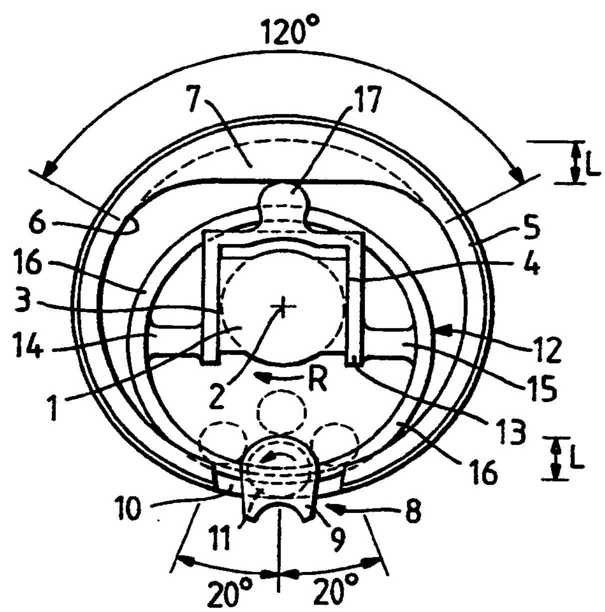


Fig. 2.

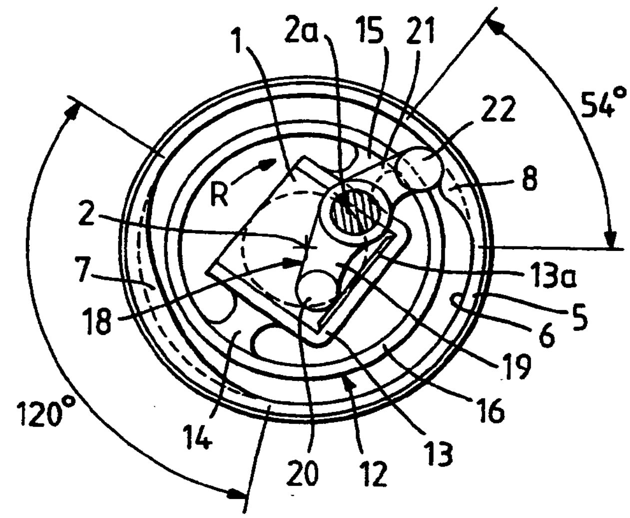


Fig. 3.

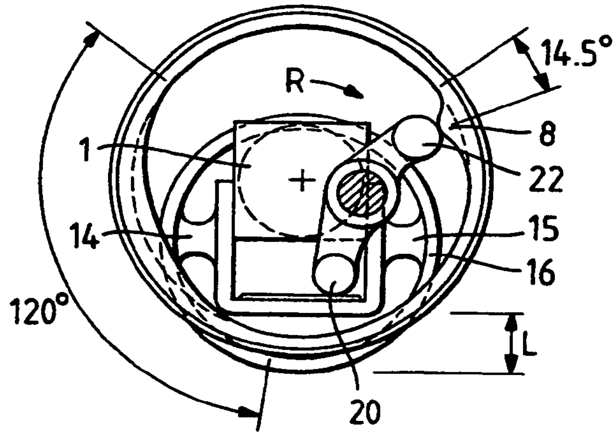


Fig. 4.

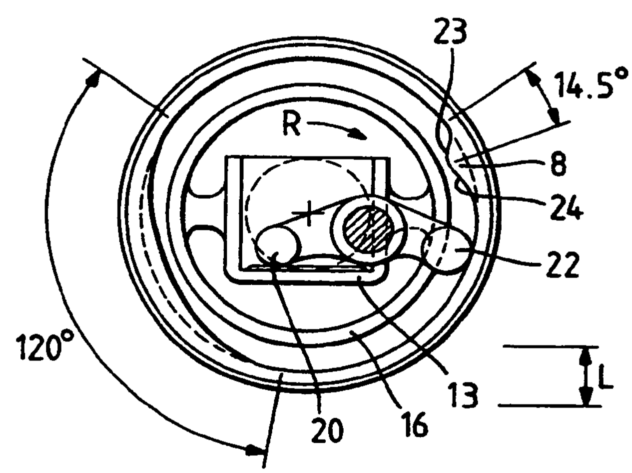

Fig.5.

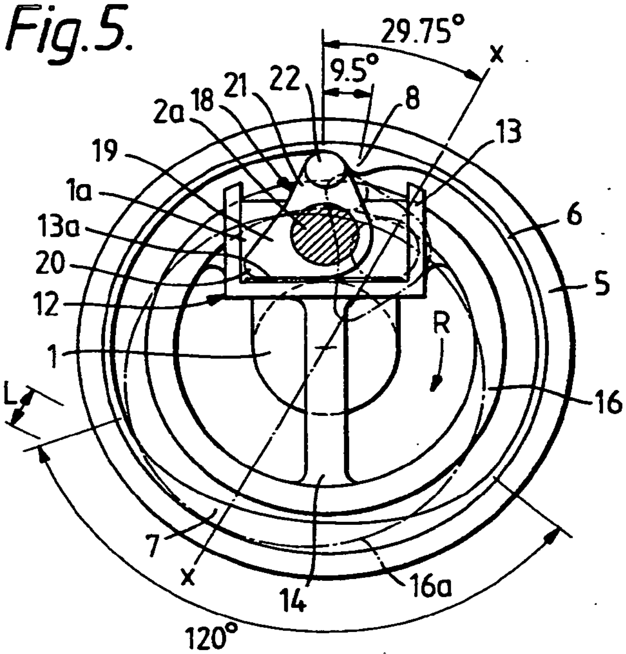


Fig.6.

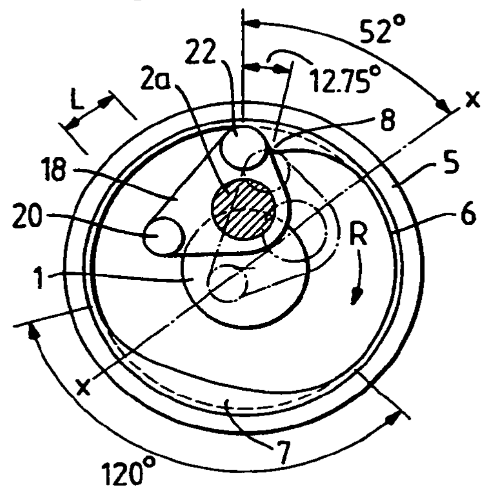


Fig.8.

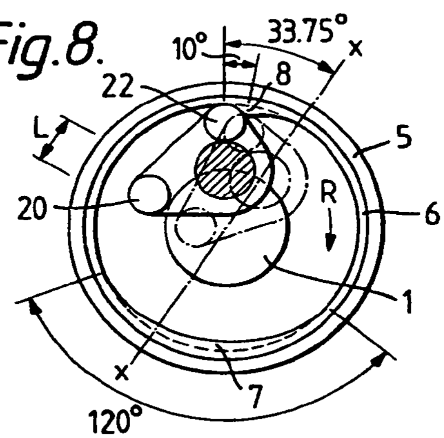


Fig.7.

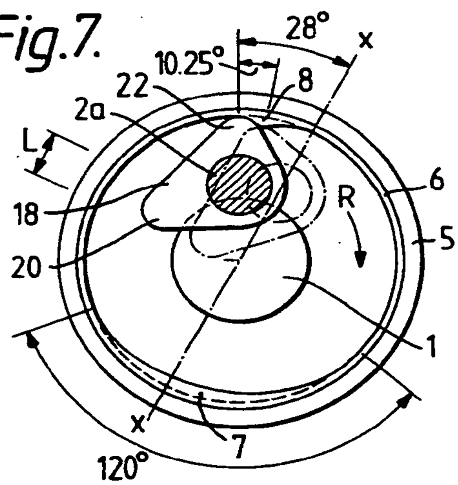


Fig.9.

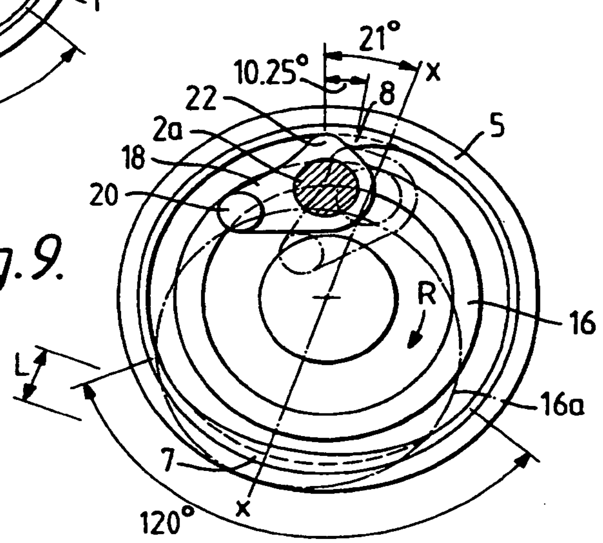

Fig.10.

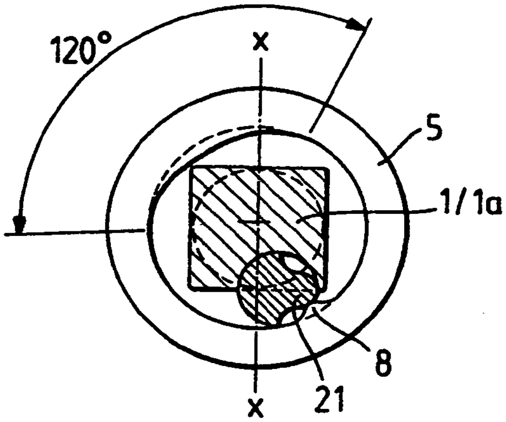


Fig.11.

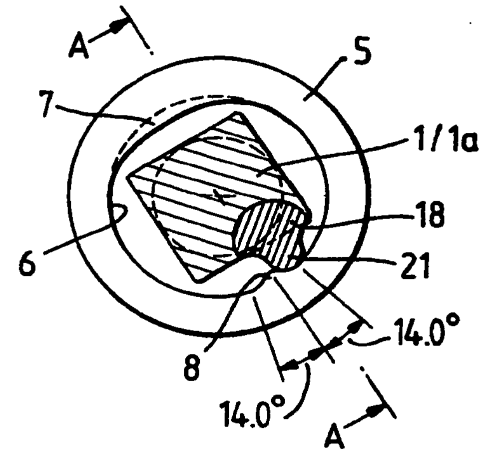


Fig.12.

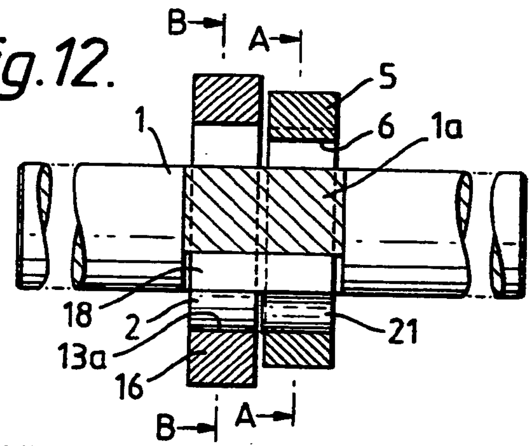


Fig.13.

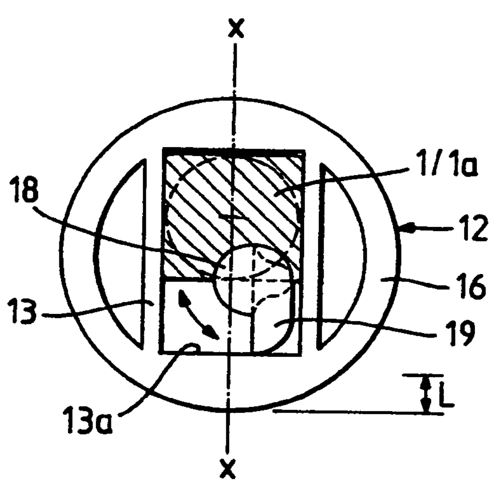


Fig.14.

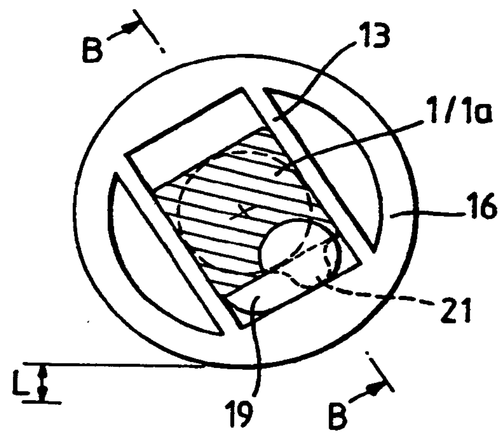

Fig.15.

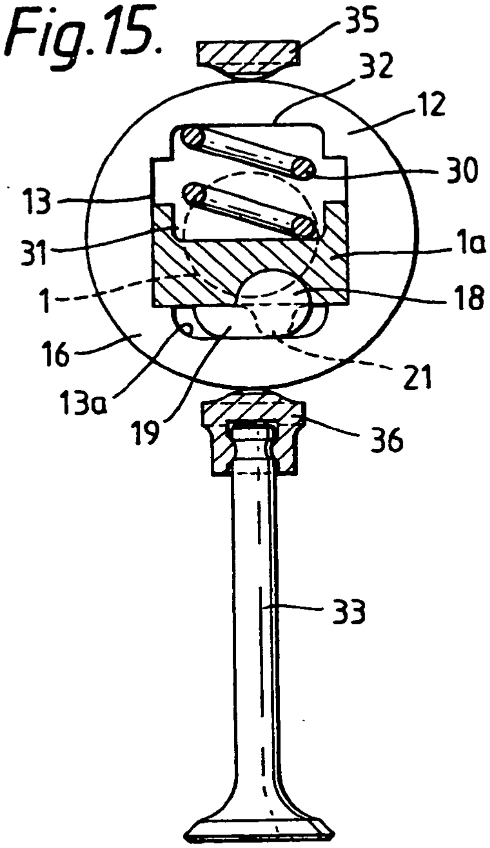


Fig.16.

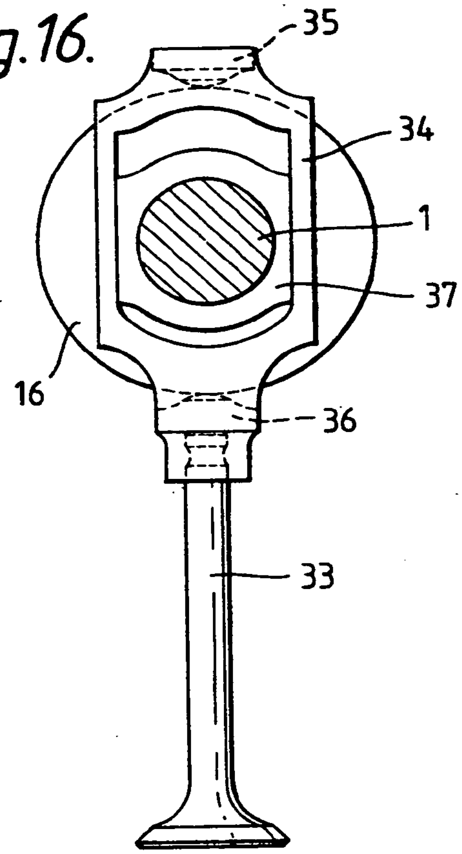


Fig.17.

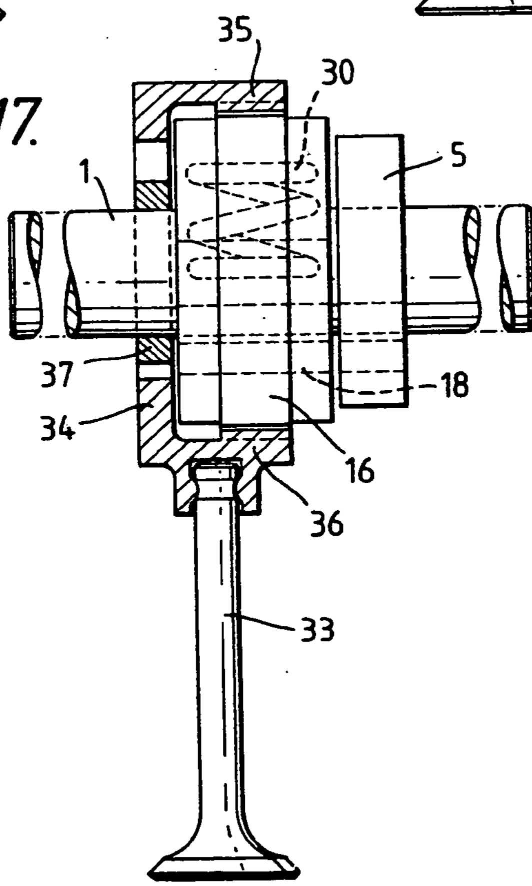

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Fig. 18.

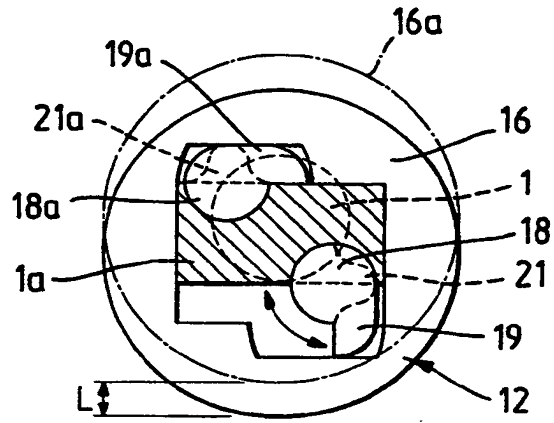
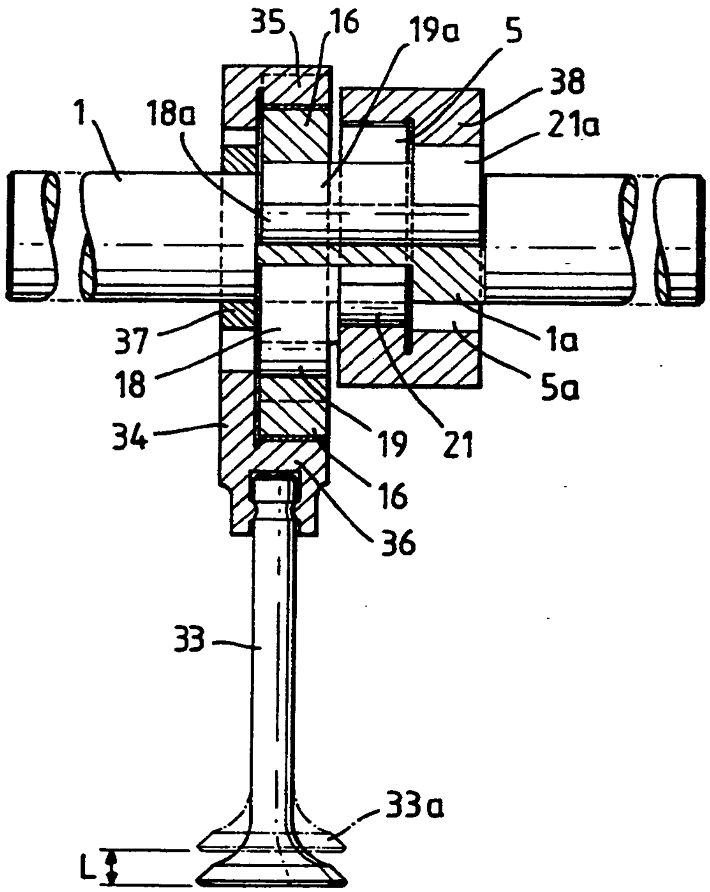



Fig. 19.



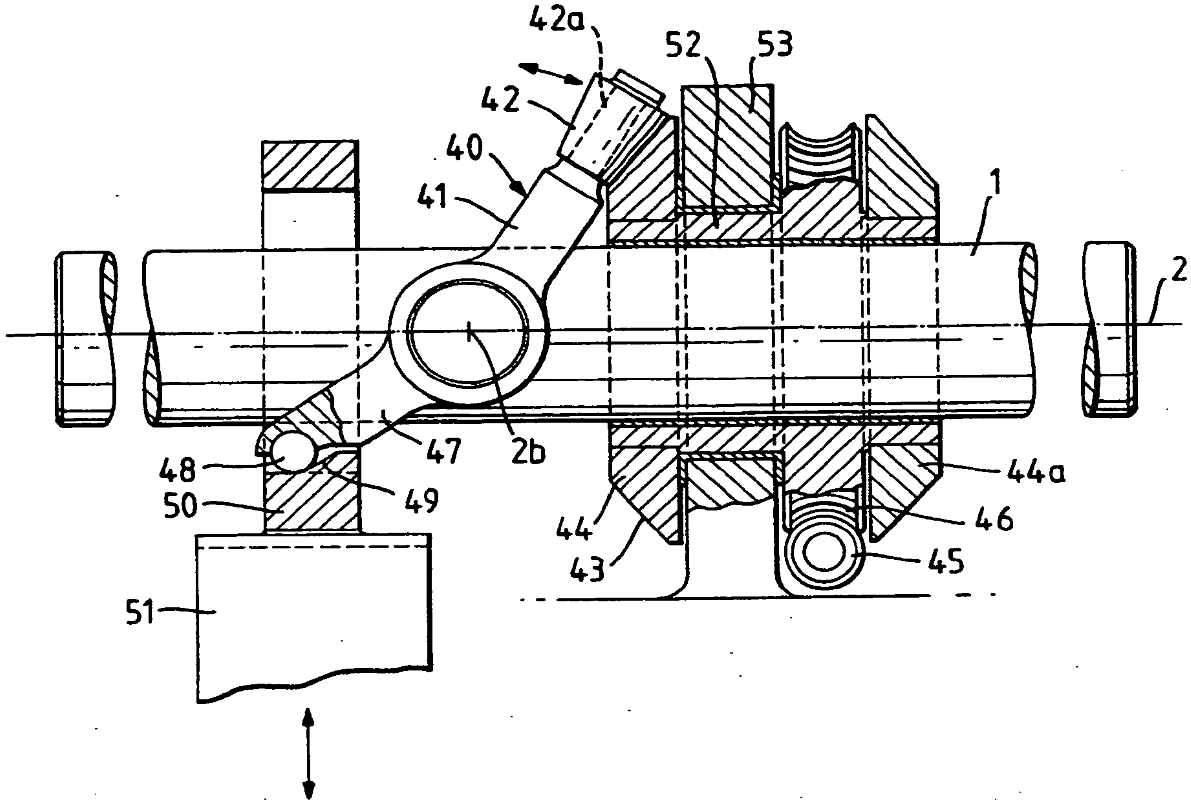

42a
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Fig. 20.

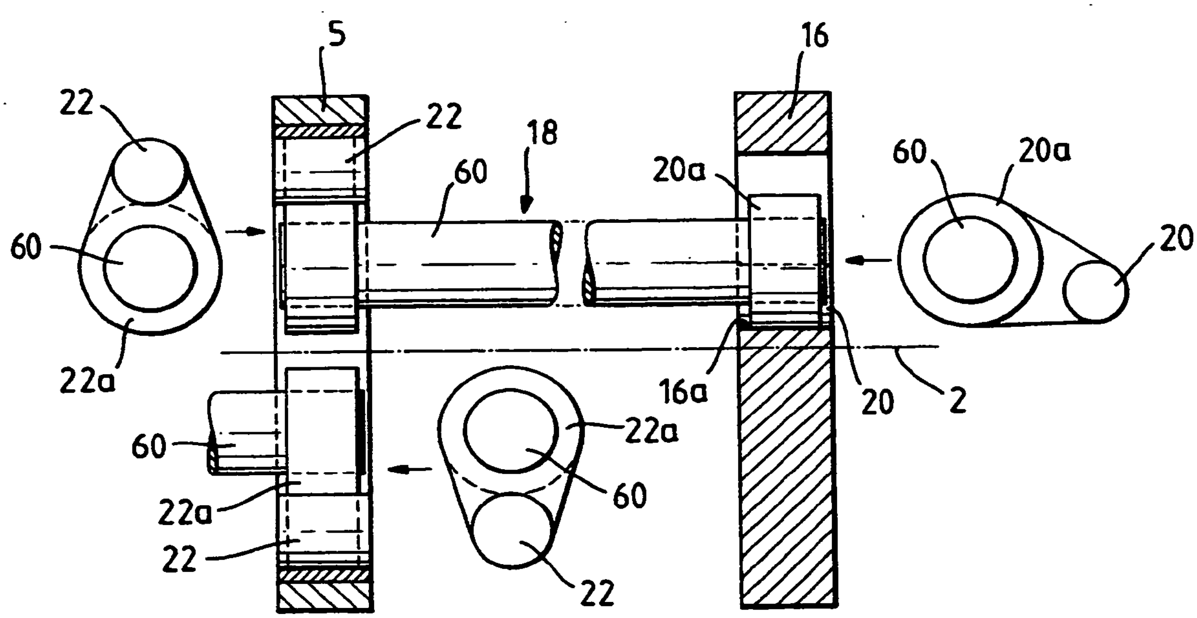
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Fig. 21.

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Fig. 22.

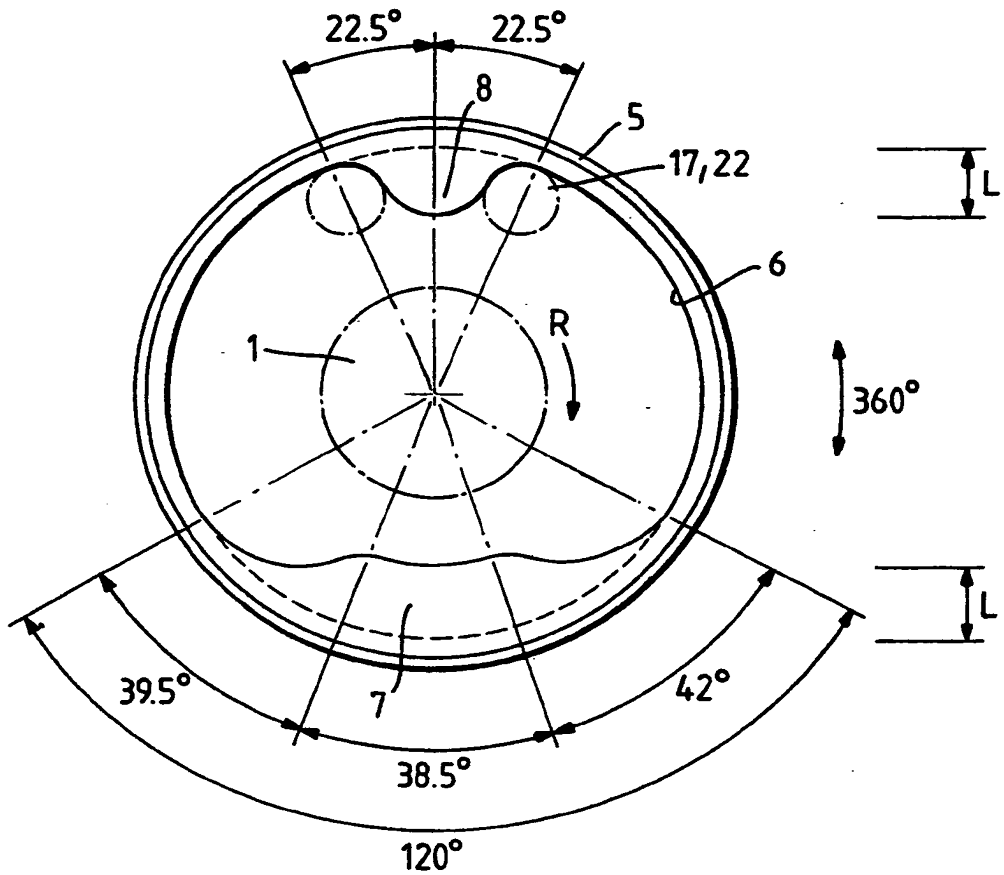
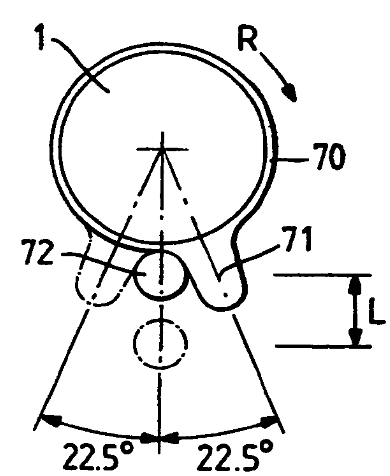



Fig. 23.



## SPECIFICATION
### Cam Arrangements

This invention relates to cam arrangements and, in particular, to arrangements for converting rotary motion into linear motion, which arrangements find particular application in connection with camshafts for internal combustion engines.

Conventionally, camshafts are provided with solid cams which rotate with the camshaft and have external cam profiles. The rotary motion of the cams is converted into linear movement of reciprocable valve members by means, such as pivotally mounted rocker arms held in contact with the cam profiles.

Solid cams suffer from various disadvantages, such as being unable to provide high-lift, short-duration valve events and having a working profile which is non-variable.

It is an object of the present invention to provide a versatile cam arrangement which deviates or at least reduces at least some of the disadvantages of known solid cam arrangements.

According to the present invention, in one aspect thereof, there is provided an arrangement for converting rotary motion into linear motion, comprising a shaft, a cam having a cam profile centred on the axis of the shaft, a slider non-rotatably received on the shaft whilst being capable of limited sliding movement on the shaft in a direction transverse to the axis of the shaft, means for effecting relative rotation between the shaft and the cam, and contact means maintained in contact with the cam profile during the relative rotation and imparting linear movement to the slider in response to an eccentric portion of the cam profile, in which arrangement the contact means comprises a rocker pivotally mounted on the shaft and having a follower arm maintained in contact with the cam profile and an actuator arm maintained in contact with an abutment surface of the slider.

In another aspect, the invention provides a cam arrangement comprising a cam having a cam profile centred on an axis of rotation and a follower maintained in contact with the cam profile during relative rotation of the cam and follower about the axis of rotation, in which arrangement the eccentric portion of the cam profile is defined by a cam surface of a lift cam element carried by the cam for movement in synchronism with the relative rotation of the cam and follower.

In a further aspect, the invention provides an arrangement for converting rotary motion into linear motion, comprising a shaft, a cam having a cam profile centred on the axis of the shaft, a slider non-rotatably received on the shaft whilst being capable of limited sliding movement on the shaft in a direction transverse to the axis of the shaft, means for effecting relative rotation between the shaft and the cam, and contact means maintained in contact with the cam profile during the relative rotation and imparting linear movement to the slider in response to an eccentric portion of the cam profile, in which arrangement the eccentric portion of the cam profile is defined by a cam surface of a lift cam element carried by the cam for rotation about an axis parallel to the axis of the shaft, and means are provided for rotating the left cam element in coordination with the relative rotation between the shaft and the cam.

In order that the invention may be readily understood, embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-sectional view of a first embodiment of a camshaft arrangement in accordance with the present invention;

Figures 2 to 4 are schematic cross-sectional views of a second embodiment of a camshaft arrangement in accordance with the present invention, showing the arrangement in three successive conditions during the rotation of the camshaft;

Figure 5 is a schematic view of a third embodiment of a camshaft arrangement in accordance with the present invention;

Figure 6 shows a modification of the third embodiment, providing a different value of lift;

Figures 7 to 9 show further modifications of the third embodiment, providing respective different values of lift;

Figures 10 to 14 schematically illustrate a fourth embodiment of a camshaft arrangement in accordance with the present invention;

Figures 15 to 17 illustrate a fifth camshaft arrangement in accordance with the present invention;

Figures 18 and 19 illustrate a sixth embodiment of a camshaft arrangement in accordance with the present invention;

Figure 20 illustrates a seventh embodiment of a camshaft arrangement in accordance with the present invention;

Figure 21 is a diagram illustrating a further camshaft arrangement in accordance with the present invention; and

Figures 22 and 23 are diagrams illustrating an advantage of camshaft arrangements embodying the present invention.

In the various embodiments illustrated in the drawings corresponding components are indicated by the same reference numerals.

Referring firstly to Figure 1, a first embodiment of a camshaft arrangement in accordance with the present invention comprises a camshaft 1 rotatable about an axis 2 and having a portion with a cross-section presenting a pair of parallel guide faces 3 and 4. The camshaft is rotatable eccentrically within an annular hollow cam 5 which has an internal cam profile 6 having a first eccentric portion 7 and a second eccentric portion 8 defined by a lift cam element 9 mounted in an aperture 10 in the annular cam 5 and rotatable with a drive shaft 11 which is rotatable about an axis parallel to the rotary axis 2 of the camshaft 1.

A slider 12 comprises a U-shaped box section 13 slidably received on the camshaft 1 and connected by brackets 14 and 15 to an output ring 16. The box section 13 is non-rotatably received on the camshaft 1, so that the slider rotates with the camshaft. However, the box-section 13 is slidable on the guide faces 3 and 4 of the camshaft, so that the slider 12 is

slidable transversely of the axis 2. The box-section 13 is formed with a follower 17 which is biased into engagement with the cam profile 6 by the spring of a valve upon which the output ring 16 acts or by a separately provided spring (not shown).

The annular cam 5 is angularly adjustable about the axis 2 through 360° and is lockable in the adjusted position. Such adjustment may, for example, be provided by means of a wormwheel formed around the external periphery of the cam 5 and engage with a worm rotatable about an axis parallel to the axis 2, the arrangement having a locking lead angle (e.g. 10°), whereby the wormwheel is rotatable by rotating the worm but the worm is not rotatable by the wormwheel. In the position shown in Figure 1, the eccentric portion 7 of the cam profile 6 is in an active position in which it causes the slider 12 to be displaced downwardly to operate the valve as the follower 17 encounters the portion 7 of the profile during rotation of the camshaft 1, while the eccentric portion 8 of the cam profile is in an inactive position in which it causes the slider 12 to be displaced upwardly as the follower 17 encounters the portion 8 during rotation of the camshaft. Each of the profile portions 7 and 8 has a centripetal eccentricity of 3.80 mm.

The eccentric portion 7 of the cam profile provides a normal opening event of the valve extending over, for example, 120° of the rotation of the camshaft and providing a displacement or lift L which is 9 mm at maximum.

Rotation of the annular cam 5 through 180° from the position shown in Figure 1 moves the profile portion 7 to the inactive position and the profile portion 8 to the active position, in which the latter effects opening of the valve. The profile portion 8 on the lift cam 9 provides a short duration opening event of the valve with high lift L. In the present example, the opening event extends over only 40° of the rotation of the camshaft and yet achieves a maximum lift of 9 mm. In order to achieve this, the rotation of the drive shaft 11 is coordinated with the rotation (in direction R) of the camshaft 2, so that the shaft 11 is driven at a rate of three revolutions anticlockwise for every revolution clockwise of camshaft 1. This may be achieved by any suitable means, such as a direct gear coupling of the two shafts at a ratio of 1:3. The relative positions of the follower 17 and the lift cam 9 in Figure 1 are such as to allow for the required alignment to take place when the follower 17 has rotated through 160° from its present position in the clockwise direction, while shaft 8 has rotated through 480° in an anti-clockwise direction. Thus, the follower 17 first encounters at position 17a the leading edge of the surface 8 and is then displaced to the position 17b of the maximum lift as the camshaft rotates through 20° and the lift cam 9 rotates through 60°. A further 20° of rotation of the camshaft and the corresponding 60° rotation of the lift cam 9 returns the follower to the position 17c in contact with the eccentric portion of the profile 6.

The described arrangement thus enables the provision of two or more selectable valve opening events of different durations and/or maximum lifts, with the possibility of one of these events being a short duration, high lift event, a situation which is impossible to achieve satisfactorily with known camshaft arrangements using solid cams. The arrangement illustrated in Figure 1 enables the provision of a short duration, high lift valve opening event in which 9 mm of lift is achieved over only 20° of camshaft rotation, with closure taking place over a similar distance, so that the whole valve event requires only 40° of camshaft rotation. Furthermore, the synchronised rotation of the lift cam element 9 enables the required steep initial ramp of cam portion 8 to be negotiated by the follower 17 without difficulty.

The camshaft 1 could be driven from the drive shaft 8 of the lift valve or drive shaft 8 could be driven from camshaft 1 or both shafts could be driven separately.

The use of a lift cam, such as cam 9 to constitute an eccentric portion of a cam profile 6 offers considerable scope for providing valve events with any desired period. Simply by choosing the correct radius of interception between the follower and the lift cam and calculating the number of degrees of rotational overlap as seen by both rotating components, the rotational ratio of the two shafts necessary to achieve synchronous interception will be determined.

Figures 2 to 4 illustrate a second embodiment of the present invention which provides an alternative method of achieving short duration, high lift valve opening events without recourse to a lift cam as shown in Figure 1.

In the embodiment of Figures 2 to 4, camshaft 1 rotates in the direction R about axis 2 within angularly adjustable annular cam 5 having cam profile 6 centred on the axis 2. The profile 6 has a first eccentric portion 7 and a second eccentric portion 8.

Slidably received on the camshaft 1 is a slider 12 comprising U-shaped box-section 13 received on camshaft 1 and connected by brackets 14 and 15 to output ring 16. A rocker 18 is pivotally mounted on the camshaft 1 by a pivot shaft 2a extending parallel to the axis 2, so that the rocker 18 rotates with the camshaft 1. The rocker 18 comprises a follower arm 21 formed with a follower 22 which is maintained in contact with the cam profile. The rocker further comprises an actuator arm 19 carrying an actuator 20 maintained in sliding contact with an abutment surface 13a constituted by the inner surface of the base of the box-section 13.

Figure 2 shows the camshaft in a rotational position in which the follower 22 of follower lever 21 is at the start of the second, short cam portion 8. Rotation of the camshaft through 54° from the position of Figure 2 to the position shown in Figure 3 causes the follower 22 to travel across an angle of 14.5° occupied by opening ramp 23 of the cam portion 8. The 54° of the cam shaft rotation cause the rocker 18 to pivot downwardly from the position of Figure 2 to the position of Figure 3, thereby causing the U-shaped section 13 to slide downwardly (as shown in the Figure) on the camshaft 1. This will cause a corresponding displacement of the output

ring 16 to open an associated valve (not shown). Given that the output ring 16 is in contact with the valve spring assembly, then the situation shown in Figures 3 and 4 will occur. Thus, if the peak of the cam portion 8 is the highest point of centripetal eccentricity and has no dwell factor, then at the instant the peak is reached, there will be no sustaining factor present to retain the follower 22 at the peak, so that without further camshaft rotation the follower could return to its original position under the influence of the valve return spring. In point of fact, a closing ramp 24 of cam portion 8 would require a profile sufficient to decelerate the return loadings and the total angular extent of the event would therefore be increased slightly above 54°.

Assuming ratios of the arms 19 and 21 are as shown in the drawings and cam portion 8 has a centripetal eccentricity of 3.80 mm at its peak, the output ring will be displaced by 13.5 mm, so that the rocker 18 has a multiplication ratio of 3.5526316:1.

The pivoting action of rocker 18 enables the steep opening ramp of cam portion 8 to be readily negotiated, thereby permitting the attainment of a high-lift, short duration valve event.

In Figures 2 to 4, the cam portion 8 is shown as being in the active position, with cam portion 7 inactive as far as valve operation is concerned. However, cam portion 7 will still cause reciprocation of the slider 12, although the movement will be directed away from the valve.

Figures 5 to 9 illustrate a third embodiment of an arrangement in accordance with the present invention employing an eccentrically pivoted rocker 18.

Figure 5 comprises a rocker 18 which is pivotally mounted on pivot shaft 2a which may, in fact, be a cranked portion of the camshaft 1. The camshaft 1 is provided with an eccentrically arranged square-section 1a and slidably receives the slider 12. The follower 22 at the end of follower arm 21 contacts the cam profile 6 of the angularly adjustable annular cam 5 and actuator 20 is in sliding contact with the abutment surface 13a of the U-shaped member 13 which is connected by bracket 14 to output ring 16. The annular cam presents a short duration cam portion 8 extending over 29.75° of camshaft rotation and a longer duration cam portion 7 extending over 120° of camshaft rotation.

Upon rotation of the camshaft 1 in the direction R, the follower 22 rides up the opening ramp of cam portion 8 to cause the actuator to displace the slider 12, thereby displacing output ring 16 to the position 16a shown in dashed lines at the point of maximum displacement, thereby effecting opening of the valve. The return spring of the valve closes the valve and returns the slider to its original position. By way of example, the cam portion may have a centripetal eccentricity of 2 mm at its peak and the lever is dimensioned to magnify the magnification provided by the lever is 4.5, so that the maximum opening or lift L of the associated valve is 9 mm, this taking place after a rotation of the camshaft through 9.5° from the position shown in Figure 5.

It is noted that it is the length of the follower lever 21 which determines the rotational extent of the opening sequence, so that the shorter this lever arm, the more immediate the opening to maximum lift. The actuator arm 19 can be extended in order to compensate very shortening of the arm 21, thereby retaining maximum lift without increasing the size of the cam portion 8.

The longer duration cam portion 7 may provide any desired lift, but as shown in the drawing it has the same 9.0 mm maximum lift capability.

Figures 6, 7 and 8 have the slider 12, camshaft portion 1a and output ring 16 omitted. Maximum lift L is indicated as being achieved, in each case, along the axis x—x.

Figure 6 illustrates two cam portions, 7 and 8, each with a centripetal eccentricity of 5 mm. The leverage of the rocker 18 magnifies this to a maximum lift L of 12.5 mm along the axis x—x at the associated valve. The maximum point of opening is obtained at 52° of rotation of the camshaft from the position shown in Figure 6.

Figure 7 shows an arrangement similar to Figure 6, but with cam portions 7 and 8 only having a centripetal eccentricity of 2 mm, giving a maximum lift of 10 mm along the axis x—x.

Figure 8 shows an arrangement having cam portions with a 2 mm centripetal eccentricity, the cam 8 providing a peak at 33.75 of the camshaft rotation and the cam 7 providing a peak at 83.75° of the camshaft rotation. It should, be remembered that the characteristics of the rocker will be reflected in both cams 8 and 7.

Figure 9 shows an arrangement having a 2 mm centripetal eccentricity in both of the cam portions 7 and 8 and shows the output ring 16 in its displaced position 16a. The total lift provided is 12 mm. In the case of cam portion 8, the peak is achieved within 21° of camshaft rotation.

Although not shown in Figures 6 to 9, the actuator of course acts against the inside abutment surface 13a of the U-shaped member 13. In all embodiments it is envisaged that the abutment surface itself may have a profile, in order to change the nature of the lever action of rocker 18 in a desired manner.

Figures 10 to 14 illustrate a fourth embodiment of the invention which has a particularly compact nature.

In the arrangement shown in Figures 10 to 14, the rocker 18 comprises a cylindrical body of circular cross-section rotatably mounted on a portion 1a of the camshaft 1 and carrying follower 21 and actuator 19 arms disposed at 90° to one another. The follower arm 21 engages the profile 6 of the angularly adjustable annular cams and the actuator arm 19 engages an abutment surface 13a of a slider 12 in the form of an integrally formed box-section 13 and output ring 16 structure.

The annular cam 5 comprises a high lift short duration cam portion 8 occupying 28° of camshaft rotation with a peak at 14° with a and a longer duration cam portion 7 occupying 120° of camshaft rotation. Both cams provide a peak lift L of 8.0 mm. Figure 14 shows no displacement of the output ring 16, while Figure 13 shows maximum displacement of the output ring along axis x—x. The centripetal

eccentricity of the two cams at peak is 2.05 mm. Normally, the actuator arm 19 is held against the abutment face 13a of the slider as shown in Figure 14 by the action of the valve spring (not shown) pushing against the output ring 16. As the camshaft 1 is rotated into engagement with the eccentric portion 8 of the cam profile, the rocker 18 is caused to rotate about its own axis, moving the actuator arm 19 away from the position shown in Figure 14 to the position shown in Figure 13, that is through 90°. This causes the slider 12 and its output ring 16 to be displaced against the action of the valve spring, thereby providing a desired valve lift L of 8.0 mm. The rocker 18 is returned to its original position as shown in Figures 11 and 14 after the peak has been achieved by the reaction of the valve return spring. The short armed rocker 18 of Figures 10 to 14 allows a very rapid opening envelope of only 14° of camshaft rotation to be achieved.

Figures 15 to 17 show a fifth embodiment of the invention which, unlike previously described embodiments, does not rely upon the normal return spring arrangement found in poppet valves, but has the necessary valve return spring built into the arrangement embodying the invention. This enables the output ring to both open and close the particular valve to which it is applied. The valve is shown in its closed position in Figures 15 to 17.

The rocker 18 employed in the embodiment of Figures 15 to 17 is similar to that shown in Figures 10 to 14 and is rotatably mounted on square-section portion 1a of camshaft 1, the box-section 13 and output ring 16 being formed as unitary slider 12. A valve return spring 30 is received at one end thereof in a recess 31 in the camshaft section 1a and abuts at the other end against an internal stop surface 32 of the slider 12. Valve 33 is carried by a valve lifter assembly 34 having a pair of calipers 35, 36 within which the output ring 16 is rotatable whilst maintaining constant contact with the calipers.

As the camshaft is rotated, the follower 21 is rolled over the cam profile of the angularly adjustable annular cam 5 causing the actuator 19 to push against the abutment face 13a of the slider 12 when an active cam portion of the cam profile is encountered, causing the output ring 16 to be displaced along the of spring 30 axis, thereby compressing the spring. This movement of the output ring causes the lifter assembly 34—36 to move in a downward direction (provided the annular cam is in a situation similar to that shown in Figure 11 and effect opening of the valve. Subsequently, the spring 30 returns the rocker 18 to its initial position and the valve is moved to its closed position.

A free-running steady element 37 is included as a simple means of ensuring linear reciprocation of the lifter assembly.

Referring now to Figures 18 and 19, a desmodromic cam arrangement constituting a sixth embodiment of the present invention comprises two angularly adjustable annular cams 5 and 5a and two rockers 18 and 18a. The two annular cams 5 and 5a are different from one another, in that the first cam 5 controls the opening cycle and the second cam 5a provides the closing cycle for an associated valve 33. The two annular cams are coupled together in a single unit 38 which is rotatable through 360° and lockable in any desired position.

If the opening cam 5 is considered to be similar to the ones depicted in Figures 10 and 11 and the closing cam 5a is a complete negative of this, then by providing respective followers 21 and 21a engaged with the two cams 5 and 5a, the rotation of the camshaft 1 will cause the rocker 18 to rotate through 90°, thereby opening the valve by the actuator 19 displacing the output ring 16 from position 16a and, as the closing ramp of the particular cam is reached, the follower 21a will come into contact with the closing cam. The closing ramp of the opening cam 5 is arranged to overlap the opening ramp of the closing cam 5a. This will cause the two rockers 18, 18a to rotate through 90° in complete antiphrase, thereby causing the output ring 16 to reciprocate. The output ring 16 is held between two calipers 35 and 36 as in the device described in Figures 15 to 17 and the valve 33 will thus be caused to open and close (33a) as required.

In order to keep requirements for precision within attainable limits, the contact areas between the actuators 21, 21a and the slider 12 and camshaft 1 may be provided with light spring (not shown) to permit a limited amount of flexibility between the two lever systems, thereby allowing for less wear and lower tolerances during manufacture. In the embodiments of Figures 10 to 19, the lever arms of the rocker 18, 18a are described as including an angle of 90°. However, any suitable angle may be used and it is envisaged that the use of angles greater than 90° will allow for better return characteristics after peak lift is attained.

Figure 20 illustrates application of the principles of the present invention to an arrangement employing a cam with an external face.

As shown in Figure 20, a camshaft 1 has a rocker 40 pivotally mounted thereon for rotation about an axis 2b perpendicular to the axis of rotation 2 of the camshaft. The rocker 40 has a follower arm 41 provided with a tapered roller 42 which is rotatable about an axle 42a and follows a bevelled external cam surface 43 centered on the axis of the camshaft and presented by a bevelled cam 44 the position of which is adjustable around the axis of rotation of the camshaft by means of a worm 45 and a wormwheel 46 combination, the wormwheel being movable with a sleeve shaft 52 passing through journal 53 around camshaft 1 and carrying the cam 44 for rotation therewith.

The rocker 40 has an actuator arm 47 provided with a roller 48 engaged with an abutment surface 49 of a slider 50 through which the camshaft passes. The slider 50 is, as in previous embodiments, rotatable with the camshaft, whilst being linearly movable transversely of the camshaft axis. The slider engages a spring bucket or tappet 51 of a reciprocable valve (not shown).

As the camshaft 1 is rotated, the follower roller 42 traverses the cam face 43 of the bevelled cam 44 and any undulations are reproduced as reciprocal movement of the slider 50. The abutment surface 49

is illustrated as having a ramp profile along the axial direction parallel to axis 2. This would allow for greater lift potential but is an optional feature.

A second bevelled cam 44a facing in the opposite direction to the first face cam 44 is illustrated in Figure 20 and is positioned on the other side of journal 53 for operating a further valve which is not shown in the drawing by means of another rocker (not shown) similar to rocker 40. Cams 44a is also attached to sleeve shaft 52.

Referring now to Figure 21, it is envisaged that the rockers 18 used, for example in the arrangement of Figure 6 of the drawing, may have an extended configuration, thereby enabling a single annular cam to operate more than one output ring. This may be achieved by providing each follower 22 with its own crank 22a which is fixed to or part of a layshaft 60. The actuator 20 of the rocker 18 is also fixed to or part of the layshaft 60 but is spaced along the shaft 60 from the follower 22 by a distance determined by the spacing of the valves. The actuator 20 is shown as having its own crank 20a and as being in contact with an internal abutment face 16a formed within an output ring 16 for actuating an associated valve (not shown). Each layshaft is carried by the main camshaft and if, for example, the annular cam 5 were situated with two cylinders of a four cylinder inline engine on either side of the cam, then two layshafts 60 would extend to the right of the cam and two would extend to the left of the cam, thereby providing drive to the valves on either side. Two long layshafts 60 and two short layshafts 60 would be required, the followers 22 being distributed around the main cam shaft axis at 90° intervals.

Although the above described embodiments of the invention employ a rotatable camshaft and non-rotatable cams, it is envisaged that the cam-shaft could be stationary and the cams rotatable.

Figures 22 and 23 illustrate the advantages over a conventional cam provided by the present invention.

In all normal internal combustion petrol engines of four-stroke design, the inlet valve, for example, is required to open only once during the four-stroke cycle; the camshaft rotating at half the crankshaft speed. However, in order that the inlet valve operates at the appropriate moment, the inlet cam is divided into 90° periods, with one such segment being radially extended outwards from the centre in order to create a lobe. The extent of the radial extension determines the amount of lift generated at the valve and the flatness of the peak defines the dwell period of the valve.

Normal external profile solid cams are unable to provide high-lift for minimal camshaft rotation, as the tangential constraints impose unacceptably high ramp angles, and wear, noise and velocity all serve to prevent the external type of cam from achieving much less than a 90° envelope or event.

Furthermore, the external cam is usually profiled in order that the event encroaches upon the periods on either side of its own designated 90°. Indeed it is not unusual for the closed/open/closed event to occupy 120° of camshaft/240° of crankshaft/rotation. As each single stroke represents 180° of crankshaft rotation, it can be seen that in such instances, there is 60° of overlap.

An annular cam arrangement embodying the present invention provides much greater flexibility, for unlike the external cam the internal cam can be provided with more than one working profile, and by rotating the annulus to a different effective position, alternative working profiles can be brought into operation. Furthermore, the same rotational adjustment can also change the overall effectiveness of any of the defined profiles within their individual events.

Figure 2 shows an annular cams with two eccentric cam portions 7 and 8. When used in conjunction with a reciprocating follower 17, 22, a displacement of 10 mm can be achieved, either as a short pulse, or as a long pulse. Furthermore, the shape of each pulse can be decided by the shape of the particular profile 7, 8.

If the output from the reciprocating follower to a valve is assumed to be downward, then in the position shown the 45° cam portion 8 is the active portion, with the 120° cam portion causing upward, ineffective displacement. However, by rotating the cam 5 through 180° and locking it in position, the active profile would become the 120° event, with the 45° event now becoming inactive so far as the valve is concerned. The fact that the reciprocating element would still be caused to reciprocate by the inactive profile is unimportant.

If a position is selected between the two portions 7, 8, then the reciprocating follower would still be caused to make two reciprocations but neither would have any effect upon the valve, thus allowing an associated cylinder of the engine to be disabled, if required.

In order to illustrate, in similar and comparable terms to those used in Figure 22, the extreme difficulty in realising a similar 45° closed/open/closed valve event with a known external profile solid cam, attention is drawn to Figure 23.

It will be seen, that in order to attempt an envelope of 45° duration, from valve closed to valve closed, profile 71 of external cam 70 becomes extreme in shape, and the conversion from rotary to linear motion will, of necessity, be of considerable disadvantage.

A further consideration, when offering comparison between the present invention and external cams, the effect of centrifugal force. In the case of an external cam, the centrifugal force tends to keep the reciprocating follower at peak, thereby allowing the cam to "disappear" beneath the follower, with the result that the follower, in the case of an extreme cam as illustrated in Figure 23 may be returned without ever touching the closing ramp. However, centrifugal forces upon the rotary reciprocating follower tend to aid the intended contact between follower and cam in the case of an annular cam. It is also clear that, while the annular cam, the external cam cannot contain more than one profile without having a positive effect upon the follower. Thus, the annular cam can be rotated in order to negate all but one active profile, or, if required, a totally negative state can be achieved.

Such selectivity is quite impossible with the conventional external cam and every complete single rotation of the camshaft will cause any profile, or profiles to have effect on the valve.

Where a motor vehicle engine manufacturer requires more than one valve operating condition, e.g. a normal event of, say, 120° or so, and also a short-duration event of say 28°/30° with maximum lift, then arrangements embodying the invention provide an answer which cannot only give two (or more) fully adjustable profiles, but can also provide these on a single component. Furthermore, the arrangements herein described can be manufactured in quantity if required, without any abnormal manufacturing procedures being required.

CLAIMS

1. An arrangement for converting rotary motion into linear motion, comprising a shaft, a cam having a cam profile centred on the axis of the shaft, a slider non-rotatably received on the shaft whilst being capable of limited sliding movement on the shaft in a direction transverse to the axis of the shaft, means for effecting relative rotation between the shaft and the cam, and contact means maintained in contact with the cam profile during the relative rotation and imparting linear movement to the slider in response to an eccentric portion of the cam profile, in which arrangement the contact means comprises a rocker pivotally mounted on the shaft and having a follower arm maintained in contact with the cam profile and an actuator arm maintained in contact with an abutment surface of the slider.

2. An arrangement according to claim 1, wherein the rocker is pivotally mounted for rotation about an axis transverse to the axis of the shaft.

3. An arrangement according to claim 1, wherein the cam is a hollow cam having an internal cam profile centred on the axis of the shaft, and the rocker is pivotally mounted for rotation about an axis parallel to the axis of the shaft.

4. An arrangement according to any one of claims 1 to 3, wherein the follower arm and the actuator arm of the rocker are spaced apart along a layshaft rotatable about the pivot axis.

5. An arrangement according to any preceding claim, wherein the contact means comprises a plurality of rockers angularly spaced apart around the shaft and each pivotally mounted on the shaft for rotation about a respective pivot axis.

6. An arrangement according to any preceding claim, wherein the shaft extends through an aperture in the slider and the cross-sectional shapes of the shaft and the slider are such that the slider is non-rotatable relative to the shaft but is linearly displaceable transversely of the axis of the shaft.

7. An arrangement according to claim 6, wherein resilient means are provided to act between the slider and the shaft to bias the follower arm into contact with the cam profile.

8. A cam arrangement comprising a cam having a cam profile centred on an axis of rotation and a follower maintained in contact with the cam profile during relative rotation of the cam and follower about the axis of rotation, in which arrangement the eccentric portion of the cam profile is defined by a cam surface of a lift cam element carried by the cam for movement in synchronism with the relative rotation of the cam and follower.

9. An arrangement for converting rotary motion into linear motion, comprising a shaft, a cam having a cam profile centred on the axis of the shaft, a slider non-rotatably received on the shaft whilst being capable of limited sliding movement on the shaft in a direction transverse to the axis of the shaft, means for effecting relative rotation between the shaft and the cam, and contact means maintained in contact with the cam profile during the relative rotation and imparting linear movement to the slider in response to an eccentric portion of the cam profile, in which arrangement the eccentric portion of the cam profile is defined by a cam surface of a lift cam element carried by the cam for rotation about an axis parallel to the axis of the shaft, and means are provided for rotating the left cam element in co-ordination with the relative rotation between the shaft and the cam.

10. An arrangement according to claim 8 or 9, wherein the cam is a hollow cam having an internal cam profile centred on the axis of the shaft.

11. An arrangement according to any preceding claim, wherein the angular position of the cam about the axis of the shaft is adjustable.

12. An arrangement according to claim 11, wherein the angular position of the cam is adjustable by means of a worm and wormwheel combination having a locking lead angle.

13. An arrangement according to any preceding claim, wherein the shaft is a camshaft and the cam actuates a reciprocable valve member.

14. An internal combustion engine comprising a valve-operating arrangement according to claim 13.

15. An arrangement for converting rotary motion into linear motion substantially as hereinbefore described with reference to the accompanying drawings.

16. Any novel feature or combination of features described herein.

Printed for Her Majesty's Stationery Office by Courier Press, Leamington Spa, 8/1987. Demand No. 8991685.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY. from which copies may be obtained.